

ON SOME EXPERIMENTS WITH DRAGONFLY LARVÆ.

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During the past few years I have kept and reared a large number of dragonfly larvæ of various species. The present paper is an attempt to collect together, in the form of a short narrative, the notes I have made about them concerning three points only, viz.:—longevity, resistance to starvation, and resistance to drought. The chief experiments carried out were made with (1) an unknown Libellulid larva of very peculiar structure, (2) a number of larvæ of *Synthemis enstalacta* Burm. I shall deal with these separately.

i. The unknown *Libellulid* larva.

On October 10th, 1908, I dredged from the loose trash (consisting mainly of half-decayed vegetable matter such as eucalypt leaves) which collects in the small pools of the Heathcote Creek (Illawarra district, N.S.W.), a large number of larvæ of *Austrogomphus ochraceus* Selys. Together with these, I found two remarkable larvæ of Libellulid form, which I am quite unable to recognise as belonging to any known species. They are very hard, and when touched, curl up into a half-ball, remaining motionless for a considerable time. They have very short legs, a somewhat triangular head, a broadly oval body absolutely flat on the underside, and a deeply and very irregularly indented labium. At the time I took them, I was already acquainted with the larvæ of every dragonfly occurring in the neighbourhood, except that of *Synthemis flavoterminata* Martin, so that it was not unreasonable to expect that this was the larva of that species. However, I have since taken, and bred out, the larva of *S. flavoterminata*, which is of an absolutely different type to the one

under our notice. I must content myself, therefore, with calling it larva X, and trust that in course of time I may be able to breed it out and solve the problem.

Of the two larvæ taken, one was killed and mounted for my collection. It is interesting to note that with this hard-skinned larva, I was able simply to drop it into boiling water, pick it out again, and mount it on cardboard, without any shrinking or change of shape taking place. The specimen is to-day exactly as it was on first mounting, and in perfect preservation. It was nearly full-fed, judging by the size of its wing-cases, which reached to the end of the third abdominal segment. The second specimen, which I kept alive, was not quite so large, and had somewhat smaller wing-cases.

During three succeeding visits to Heathcote, in October and November, 1908, I was very disappointed at failing to obtain another specimen of this peculiar larva. Nor have I succeeded during 1909 and 1910, in obtaining a single specimen, though I have carefully dredged the creek several times. Nor have I, amongst the numerous exuviae collected, ever found this species.

I did not doubt, for a moment, when I first placed this larva in a small jar for observation, that I should succeed in breeding it out during the summer of 1908-09. I supplied it with plenty of food, chiefly mosquito-larvæ and small insect-larvæ picked out of the trash of the creek-bed. In the jar there was plenty of water-weed growing, and a strong stick was placed in an upright position for use on emerging. The larva settled at the foot of this stick *head downwards*, ate three mosquito-larvæ which I drove almost into its mouth, and then remained in this position, day after day for weeks, without taking the slightest interest in anything. Once or twice I got up at midnight and found it climbing up the side of the jar or walking round the edge, so that I concluded that it was a nocturnal feeder.

By the middle of December, 1908, all the other larvæ which I had collected had emerged. The larva X was, however, still in its old position on the stick, had undergone no ecdysis, and did

not appear likely to emerge for a long time. As I was then leaving for Tasmania, I covered the jar with a muslin top, put in a good supply of food, and left it.

I returned on January 25th, 1909. I found the water in the jar almost evaporated, the water-weed growing rather thickly on the damp sand, and the larva still in the same position on the stick, but with its head partly buried in the damp sand. It was evident that it could withstand these semi-drought conditions; so I allowed them to continue for nine weeks, viz., up to the end of March. During that time, I sprinkled water on to the sand with my fingers about once a week, so that the sand did not get absolutely dry, nor did the weed completely die away. No food of any kind was supplied to the larva, which evinced no desire even to move, much less to feed. On April 2nd, fearing that a continuance of these conditions might prove too much for the larva, which I did not wish to lose, I filled up the jar with tap water. As the larva still remained in its old position, I did not put any food in, but left it to itself throughout the winter. Though I watched it very often, both night and day, it never once changed its position, nor showed any sign of life.

It remained thus until the end of September, 1909. By this time the water-weed was growing again, and a good crop of duck-weed covered the surface of the water. The temperature of the water was now considerably higher than during the winter. On September 29th the larva awoke from its long period of hibernation, and began wandering round the jar. I put in a number of mosquito-larvæ, but the dragonfly larva seemed frightened at them, and kept continually backing away from them. However, when at last I managed with a stick to drive one wriggling straight to its head, it snapped at it and swallowed it whole. I succeeded in getting it to eat two more. At night I noticed it to be on the look-out for food, and I have no doubt it secured a good meal. During the next few weeks it usually occupied a position on the stick, sometimes head downwards and sometimes head upwards; occasionally half-way up, but usually at the base of the stick.

Meanwhile its colour darkened from a semi-transparent brown to a dark'opaque blackish-brown, indicating the approach of an ecdysis. On November 3rd it changed its skin. I was fortunate in seeing the change, which occurred in the early morning and took a considerable time—nearly an hour. The larva on emerging from its skin was of a very pale green colour, but on my return in the afternoon it was quite brown again. I do not know of any other dragonfly larva in which the skin hardens and darkens so quickly after ecdysis.

I now had hopes that this larva, already more than a year old, would emerge during the summer of 1909-10. But although it was plentifully supplied with food, it seldom took a meal, and grew very slowly. By the beginning of March it had settled down again in its old position at the base of the stick. Though it occasionally wanders about at night, it keeps in one position during the day. To-day (June 11th, 1910) it is still quiescent. As it is now nearly midwinter, it will evidently not emerge until October or November, at the earliest.

The conclusions I make from these observations are:—

(1) As regards *longevity*. Dragonfly larvæ of some species can, and do, live for more than a year; under adverse conditions, they can live more than two years. Even supposing that the ovum from which the larva X sprang was laid as late as February, 1908, and hatched, say, in March, this larva is now *two years and three months old*. And as it was already so far grown, when I took it in October, 1908, as to possess small wing-cases, I do not think we can possibly suppose that it was hatched later than March, 1908.

(2) As regards *resistance to starvation*. The larva X certainly had no food from January 25th, 1909, to September 29th of the same year, *i.e., for eight months*; and probably it had gone without food for a month previous to January 25th, during my absence from Sydney.

(3) As regards *resistance to drought*. The larva X, taken from a clear mountain-stream which is never dry, withstood a considerable degree of drought *for nine weeks*. As I did not allow

the sand to dry up completely, so as to cake into a hard mass, we cannot say from this that it could have survived a more vigorous drought. But in its natural haunts, supposing at any time a long-sustained drought had occurred, there would have been at times a fall of dew which would have served the same purpose as the sprinkling of water which I gave once a week.

ii. The larvæ of *Synthemis eustalacta* Burm.

About twenty of these were obtained from a swamp at Leura, Blue Mountains, on October 1st and 2nd, 1909, together with about a dozen larvæ of *S. macrostigma* Selys, all from one-half to three-quarters grown in size. As these larvæ are incapable of climbing out of a deep glass aquarium, I placed them in a specially designed circular tank, one yard in diameter, with sides only six inches high. From two to three inches of sand covered the bottom all over, rocks were placed here and there, clumps of water-weed planted, and the tank filled with water to within half-an-inch of the brim. A large quantity of duck weed was placed on the water, and clumps of reed and sedge placed so that the larvæ could climb up and emerge.

In the previous year, nearly all my larvæ of these two species died through inability to emerge from a deep aquarium when full-fed. During November and December, 1909, however, all the larvæ of *S. macrostigma* emerged, and also many of the *S. eustalacta* larvæ. There were, as a matter of fact, eight of the latter larvæ in the tank on December 25th, 1909, together with two *Hemicordulia tau* and a few small *Agrionid* larvæ (*Pseudagrion cyane*). I determined to subject these to a rigorous drought and starvation process. To do this naturally, no more food was put in, and the water was allowed to evaporate of its own accord. Also, in the centre of the tank, two flat rocks were arranged, so that one leaned slantwise on the other, forming a small "haven of refuge," which I could at any time examine, by lifting the slanting rock, without disturbing the larvæ.

By February 2nd the water had all evaporated, but the sand was still very damp, especially around the rocks. A week later

all the *Agrionid* larvæ, and the two *Hemicordulia tau*, were dead—stretched, flat and dried up, on the sand*. In the “haven of refuge” three larvæ of *S. eustalacta* had settled down into the damp sand. The other five were wandering round the tank searching for damp corners, under the rocks. I noticed that they appeared to be considerably annoyed by a tiny fly which settled often on their backs. It will be interesting to find out whether the larva of this fly is a parasite on the living dragonfly larva.

On February 16th, there was only one *S. eustalacta* larva in the “haven of refuge.” This one was caked all over with dry sand, and I picked him up and examined him. He was quite vigorous, and ran across my hand. I put him back again, and noticed that the other two had crawled to the edge of the tank and had got partly under the shelter of a large flat rock near the edge. The sand was now absolutely dry, and caked hard. The tank was left without observation from this date until Good Friday (March 25th). On that day I turned up the slanting rock in the centre, and found the same larva of *S. eustalacta* sitting under it in exactly the same position as when I left it. It was quite lively, and ran vigorously across my hand. It appeared very hard and dry, caked with sand, but not at all shrivelled or reduced in size. I then turned up the other rocks, and discovered three more larvæ of the same species, firmly set into the dry sand. These came out like dry hard lumps in a cake of sand. They were absolutely inert, and to all appearances dead, but not shrivelled, and only a little reduced in size. I dropped these three into a jar of water. Two of them revived immediately, and swam to the bottom of the jar, where they buried themselves at once, with just their heads and anal ends appearing above the sand. The third larva floated on the water for half-an-hour, when he suddenly revived and descended to the bottom of the jar, where he sat on the sand without attempting to bury himself.

* It is interesting to note that before the very dry winter of 1907, huge swarms of *Hemicordulia tau* appeared during March and April all over New South Wales. Many followed the watering-carts in Sydney for weeks, and the occurrence was noted in the daily press.

These three larvæ were supplied with a jar full of mosquito larvæ (about two or three hundred). As these wriggled past them, they seized and ate with the utmost greed all that they had time to catch. One larva ate over fifty mosquitoes in ten minutes, but after that refused to eat any more until the next day. These larvæ are now in one of my large aquaria; are feeding well and appear to be nearly full-fed; but I do not now expect them to emerge until next November.

The remaining larva was again returned to his place under the middle rock*. The tank was then left without observation for just over five weeks, *i.e.*, until Sunday, May 1st. On lifting the middle rock on that date, I found that the larva had deserted his old haunt. I examined the other rocks, and found him buried flat under one of them, so I carefully replaced the rock upon him. I was quite unable to find any other larvæ, though I knew that there should be three or four more somewhere.

Another month was now allowed to pass. On May 29th I again lifted the rock under which I had left the larva. It was still there, but appeared somewhat shrivelled and inert. Fearing that it had about reached the limit of endurance, and desiring to preserve it and breed it out at a later date, I now removed it and dropped it into an aquarium. It revived at once, swam to the bottom, and began a vigorous onslaught on the mosquito-larvæ with which I supplied it. It is to-day alive in the aquarium and feeding well.

Regarding the experiment now as practically ended, I removed and examined all the rocks. I found no larvæ under any of them. I then took a watering-pot and watered the sand all over until it was soaked completely through. In a few minutes bubbles appeared in various places, and there crawled out two or three specimens of a small dark centipede, several small red worms of a kind I have often seen in fresh-water ponds, and *four*

* This larva was kept in a small box of dry sand from Friday, April 25th, to Wednesday, April 30th, and was exhibited on the latter date at the meeting of the Linnean Society. Vide Proceedings *antea*, p.48.

more larvæ of S. eustalacta These latter were placed in a separate aquarium. Three of them attempted to swim downwards, but could not, as their bodies were so light. They then took up a position similar to that adopted by *Notonecta*, walking under the surface of the water, with legs uppermost. In this position they caught and ate a fair number of mosquito-larvæ. A few hours later they managed to swim to the bottom. It was ludicrous to see their attempts at covering themselves with sand. No sooner had they heaped a fair quantity on to their backs, and striven to settle down flat in it, than the buoyancy of their bodies overcame them, and they rose helplessly up into the water. To-day, a fortnight later, only one has so far succeeded in burying itself. The other two sit on the lead at the corner of the aquarium and feed quite contentedly.

Finally, the fourth larva floated, to all appearance dead, for six hours. It then showed signs of life, and adopted the *Notonecta* attitude. It remained thus for five or six days, feeding well. It is now able to crawl about in the water-weed, but is still too buoyant to keep on the sandy bottom.

Of the eight larvæ I now possess, which have passed through this trying ordeal, I trust that some will emerge next summer. It will be most interesting to see the effect of their experiences on the size and colour-pattern of the resulting imagines.

I should like to add that I was most careful to test the dryness of the sand, *below the surface*, by digging; and satisfied myself that on February 16th the sand was *absolutely dry and caked hard throughout*, right down to the bottom of the tank. (The total depth of sand was only three inches).

The chief conclusion to be drawn from this experiment is that the larva of *Synthemis eustalacta* possesses the power of resisting drought to a most remarkable degree. This is all the more surprising, inasmuch as none of the species of this genus are found in the drier parts of Australia. On the Blue Mountains, where I obtained the larvæ, the *average* rainfall is very heavy, ranging from 30 to over 50 inches per annum. Droughts, however, of some duration are known to occur. The test that I

applied, which amounted to a severe drought of ten weeks' length, without even the help of a single fall of dew through the whole period, is, I think, sufficient to prove that the members of this genus can easily survive the driest conditions they are ever likely to meet with in their natural habitat. This is of great interest, since I have noticed that most dragonfly larvæ, such as nearly all the *Æschnidæ* and *Agrionidæ*, with not a few of the *Libellulidæ*, perish as soon as the pond or river containing them dries up. It may go far to explain the peculiar success of the *Synthemis*-type in Australia, and the manner in which they have survived and successfully held their own against more highly evolved types in all parts of the continent. As regards those few *Libellulidæ* which appear to have established themselves permanently in the desert belt of Central Australia (and whose larvæ therefore we might expect to possess a drought-resisting power superior to that of *Synthemis*), we are not yet in a position to know whether it is really their larvæ which withstand drought, or whether the imagines themselves may not scatter far and wide over the heated sandy plains, and so always keep the race alive over a large area, by ovipositing in whatever waterholes may happen to contain water at any given period. As far as I know, only *Orthetrum caledonicum* and *Diplacodes hæmatodes* occur commonly over the whole of Central Australia; and these two dragonflies are noted above all others in Australia as being *sand-lovers*. Even in well watered regions they seek out the dry patches of sand and settle on them in hundreds. Also, whereas the seasonal range of the imago in *Synthemis* is comparatively short (from the end of November to the end of February), that of the above-mentioned species is long. They occur all the year round in tropical parts, and in New South Wales they may be taken from early in September right up to the beginning of June.

The experiment also shows that the larvæ of *Synthemis*, when conditions are unfavourable to development, can and do remain alive for more than one year. As *S. eustalacta* is only on the wing from November to February, and most of the ovipositing is

done before February, these larvæ must at any rate have been hatched by March. So that they are now *fifteen months old*.

As regards resistance to starvation, these larvæ went without food for about three months, and I have no doubt could endure a longer fast if necessary. Often, in the winter, their mountain haunts are frozen up, and they are compelled to go without food. As regards *S. macrostigma*, which inhabits the thick mud at the *edge of* a mountain bog, it is probable that it is often completely enclosed in the hard cake of frozen mud in which it lives, without being any the worse for it.

In conclusion, I find that, as far as my experiments go, most dragonfly larvæ can go without food for long periods. I suspect that many others besides those which were made the subject of these experiments are able to exist as larvæ for two or even three years. I do not, however, think that many can resist drought; that is a power possessed only by a few *Libellulidæ*, and possibly also by *Petalura* and *Argiolestes*.

POSTSCRIPT (*added 18th October, 1910*).—Since this paper was read, much that is of interest has occurred with regard to the unknown *Libellulid* larva mentioned therein. By the middle of September it appeared quite full-grown, and on several successive days it moved up the twig and rested partly out of the water. However, the weather not being very warm, it returned again to the bottom of the jar, and became very listless and inert. On October 7th, it emerged from the water, and climbed well up the twig, resting some three inches above the surface of the water. There it remained all day, unable to effect the final change. The weather was rather cold and exceedingly windy, so that it was unfortunately by no means a good day for a successful emergence. On my return home I found that the larva had fallen off the twig dead. Its thorax was much swollen, and the parts of the head were dry and partly cracked; so that it was evident that the final change had begun, but that the larva had lacked strength to complete it. How far this failure was due to unnatural conditions I cannot say, for the larva was quite strong and healthy until a few days before it died.

I was much disappointed at this failure to breed out such an interesting larva, after having kept it just over two years. However, I carefully removed the wing-cases from it, and, with some trouble, I was able to stretch out the wings nearly to their full size, and to sketch all the important parts of the venation. As a result of a short examination of them, I am able to state that the larva belongs to a hitherto unknown species of the subfamily *Corduliinae*, which will form the type of a new genus allied to *Syncordulia*. It is strange that, after having collected carefully at Heathcote for so many years, and at so many different times of the year, I have not yet met with the imago. To obtain it will now be one of my principal aims.

I visited Heathcote again on October 1st of this year, for the purpose of obtaining more of these larvæ. Careful dredging for some hours yielded no results, but finally, amongst a large collection of trash washed down by the rains into a deep pool, I found no less than six of them. They are all small, the largest being smaller than the one I originally found on October 2nd, 1908. These are now in my aquarium, and will be watched with great interest. They will probably take two, or possibly three, years to reach maturity.